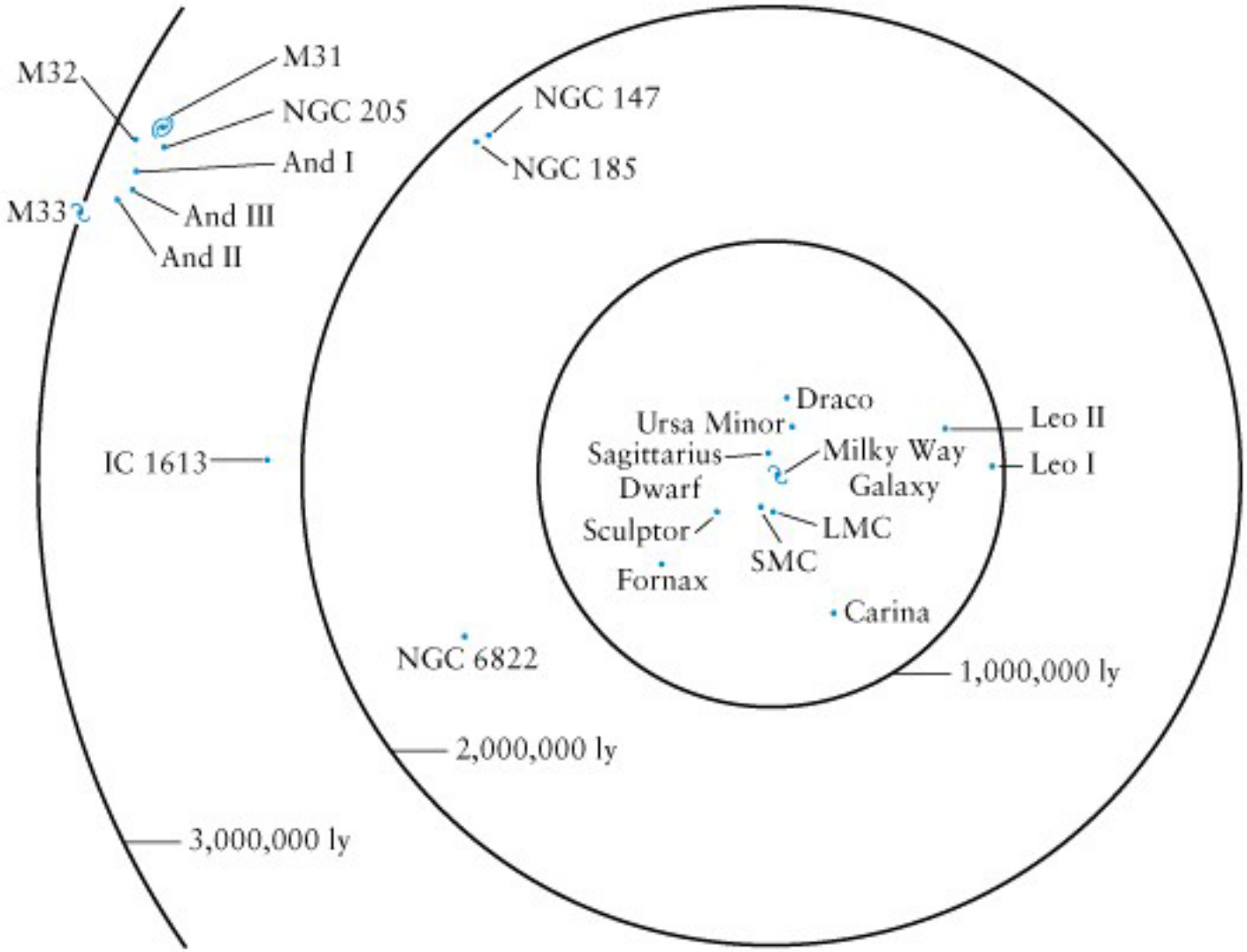
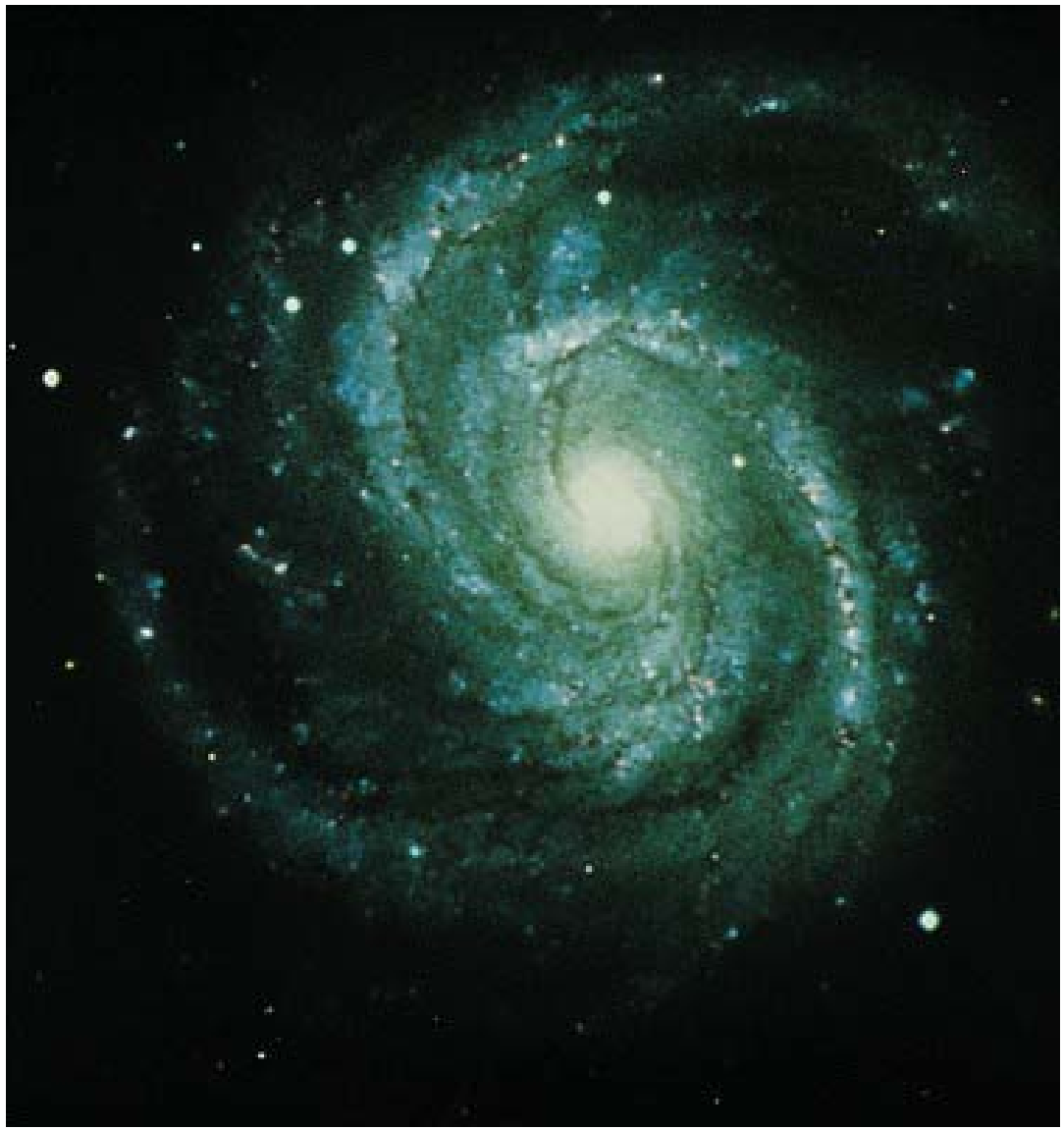
The Milky Way Galaxy


M32
M31
NGC 205
And I
M33
And III
And II
NGC 147
NGC 185
IC 1613
Draco
Ursa Minor
Leo II
Sagittarius Dwarf
Milky Way Galaxy
Leo I
Sculptor
LMC
SMC
Fornax
Carina
NGC 6822
1,000,000 ly
2,000,000 ly
3,000,000 ly

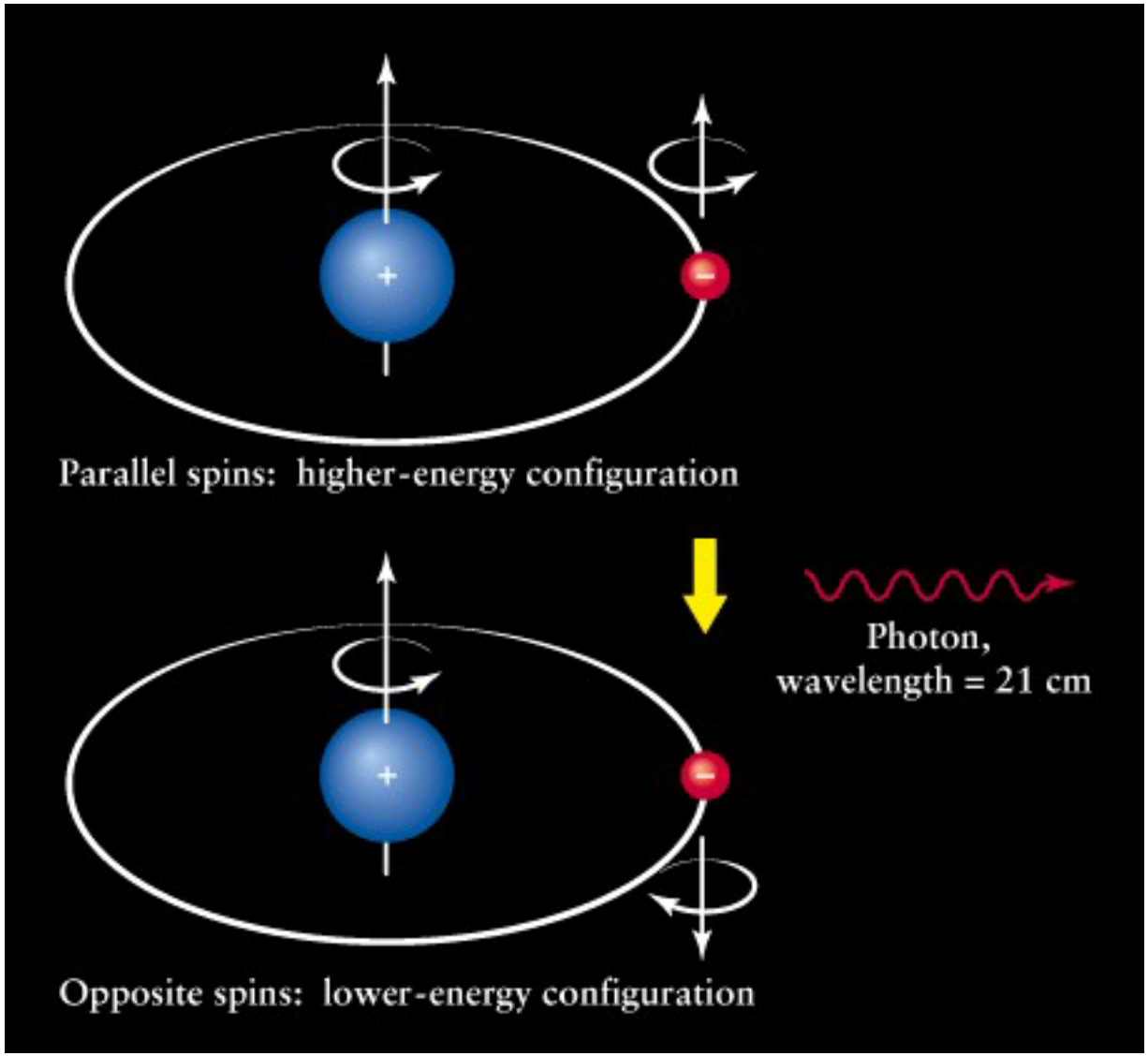
What do you think?

- Where in the Milky Way is the solar system located?
- How fast is the Sun moving in the Milky Way?
- How many stars are in the Milky Way Galaxy?



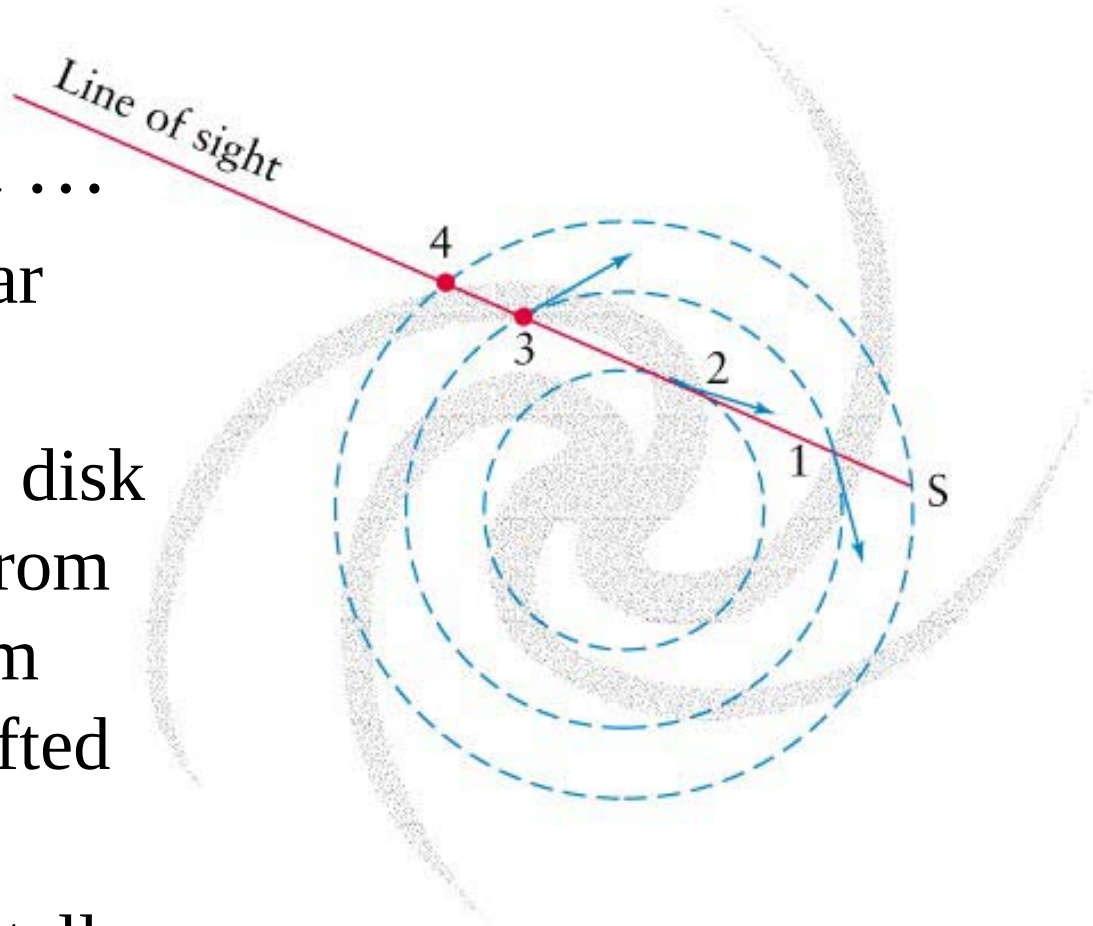
The Milky Way is composed of all the stars in our galaxy, nearly 400 billion. All the stars you can see in the sky are in our Galaxy.

Enormous clouds of dust obscure our view of most of the stars in our Galaxy

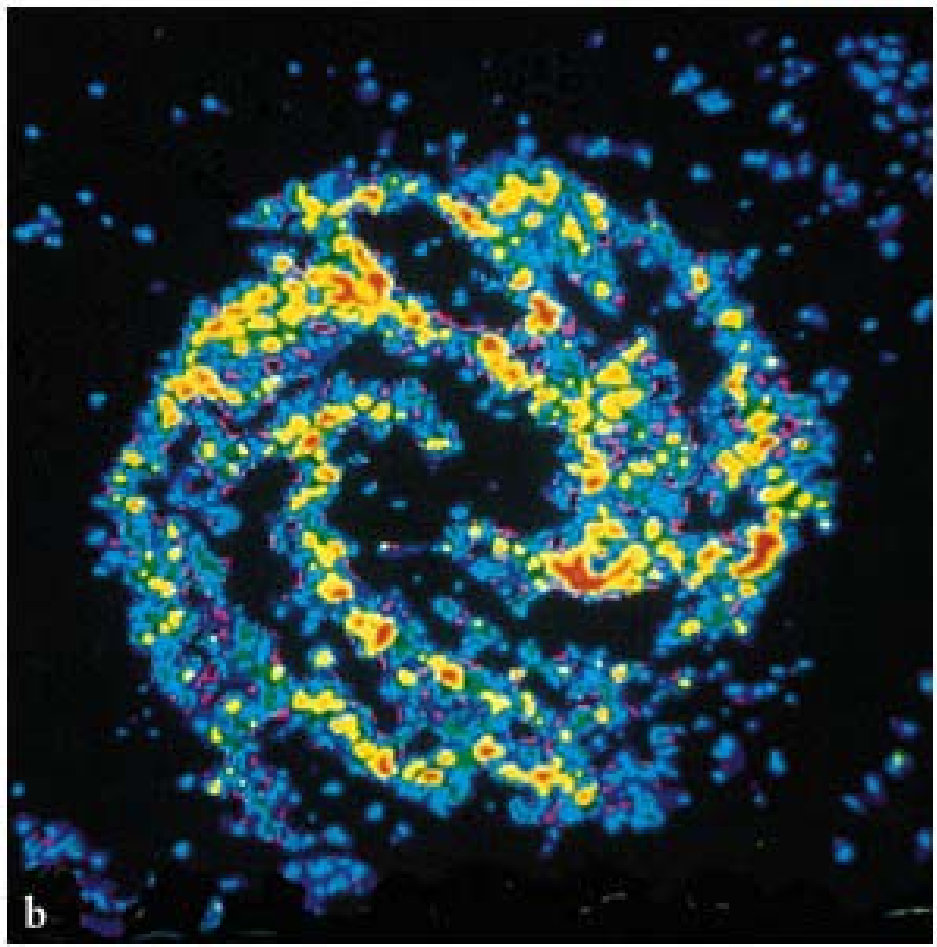

Parallel spins: higher-energy configuration
Photon,
wavelength = 21 cm
Opposite spins: lower-energy configuration

Radio observations help map the galactic disk

- Looking for 21-cm wavelengths of light …
  - emitted by interstellar hydrogen
  - as we look along the disk of the Milky Way (from inside), we see 21-cm photons Doppler shifted varying amounts
  - this allows the interstellar hydrogen to be mapped

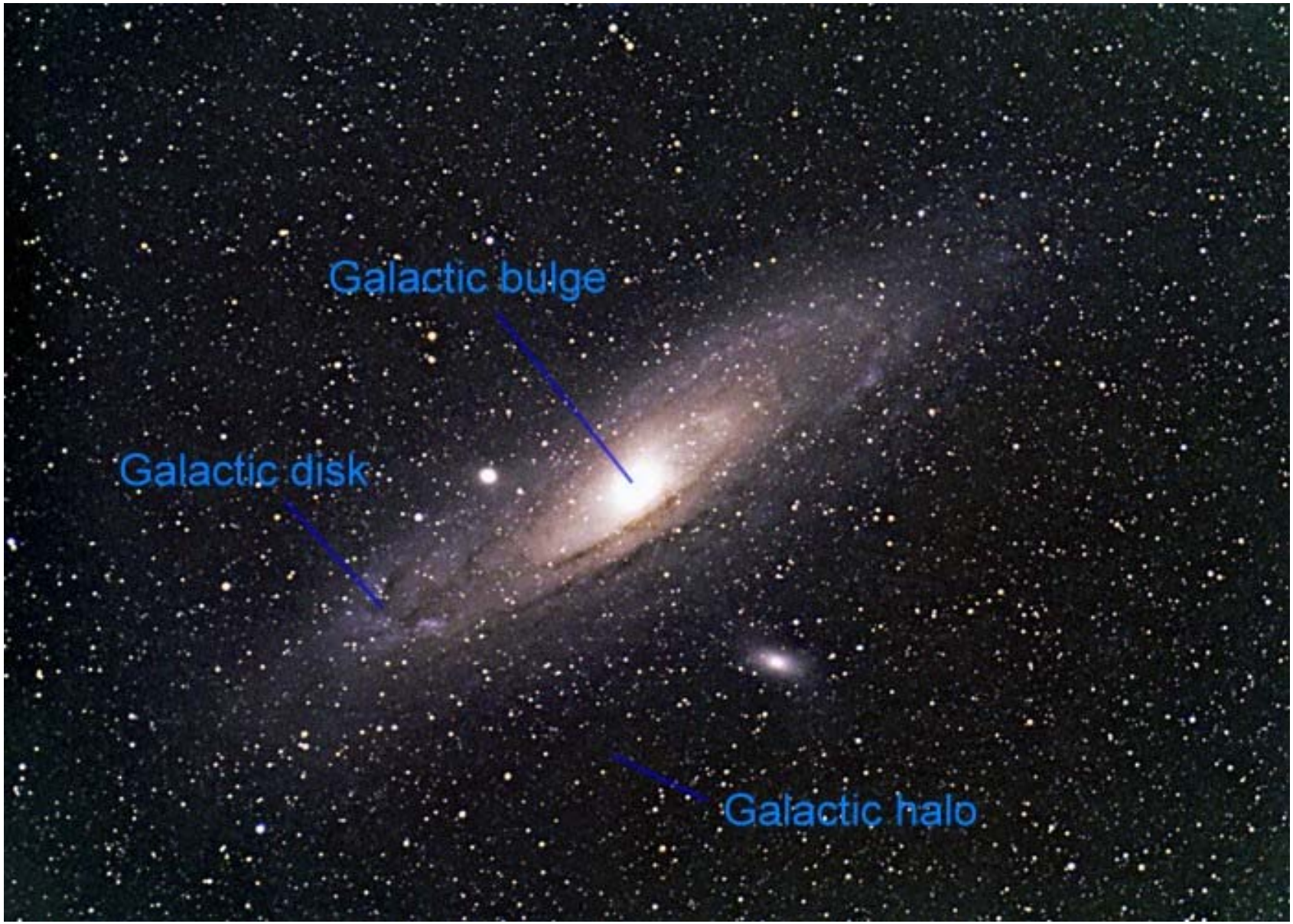


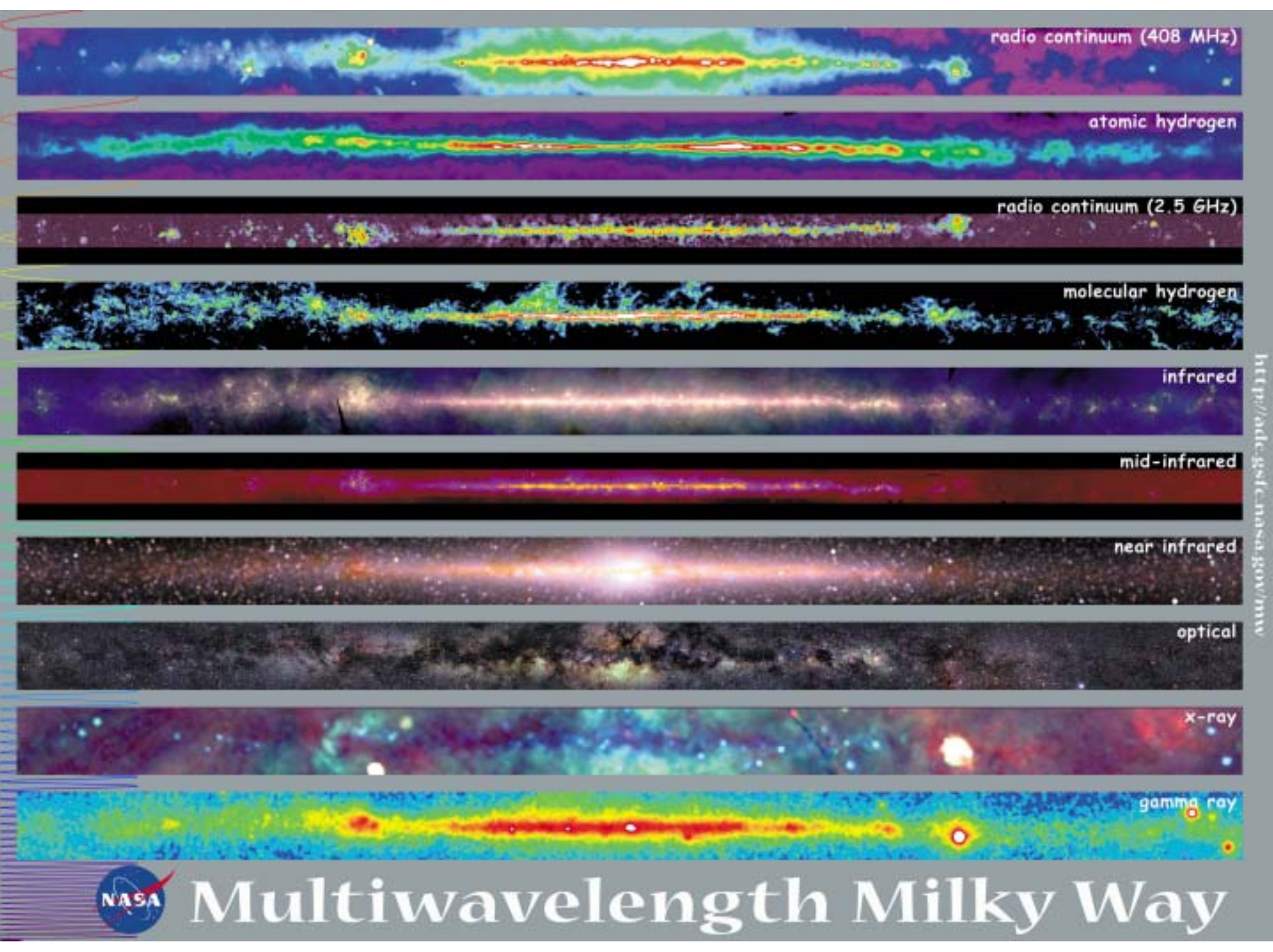
Spiral Galaxy M83 observed in both visible light and radio wavelengths.



Components of the Milky Way

- Stars
- Interstellar gas and dust
- Magnetic field


Galactic bulge
Galactic disk
Galactic halo


radio continuum (408 MHz)
atomic hydrogen
radio continuum (2.5 GHz)
molecular hydrogen
infrared
mid-infrared
near infrared
optical
x-ray
gamma ray
http://adc.gsfc.nasa.gov/mw
NASA
Multiwavelength Milky Way

Stellar Population

- Baade (1944, in LA, Mt Wilson) on nearby ellipticals, and spheroidal components of spirals
  - **Pop I** **---** luminous blue stars, associated with dust and gas
  - **Pop II** **--** luminous red stars, in gas- and dust-free environment
- Open clusters and stellar disks -- Pop I
- Globular clusters, galactic spheroids, and elliptical galaxies -- Pop II

- Now understood as an evolutionary sequence: globular clusters and spheroid of the Milky Way (Pop II) formed first, with the Pop I stars in the disk forming later.

  Population I stars --- young and metal rich

  Population II stars -- old and metal poor

- [Fe/H] = log N(Fe)/N(H) - log $(N(Fe)/N(H))_{\odot}$ observed value from +1 (some stars in the central bulge of the Milky Way) to -2.3 (most metal-poor globular clusters)

- But even the most metal-poor stars in the Milky Way contain trace amounts of heavy elements, which they could not have synthesized themselves

  → Pop III stars of even earlier generation?
- Yet need observational evidence

Thin disk

- double exponentials, both in radial direction (scale height of a few kpc) and in z (scale height of a few hundred pc)
- stars move in almost circular orbits around the Galactic center
- ~ solar abundances; lower abundances with increasing galactocentric distances
- At the location of the Sun, the disk is ~300 pc thick, or 1/100 of its diameter

Stellar halo

- globular clusters and field stars
- globular clusters: halo globulars and disk globulars, with morphological, kinematic, and chemical differences

Dark halo

- the massive surrounding component that causes the flat rotation curve

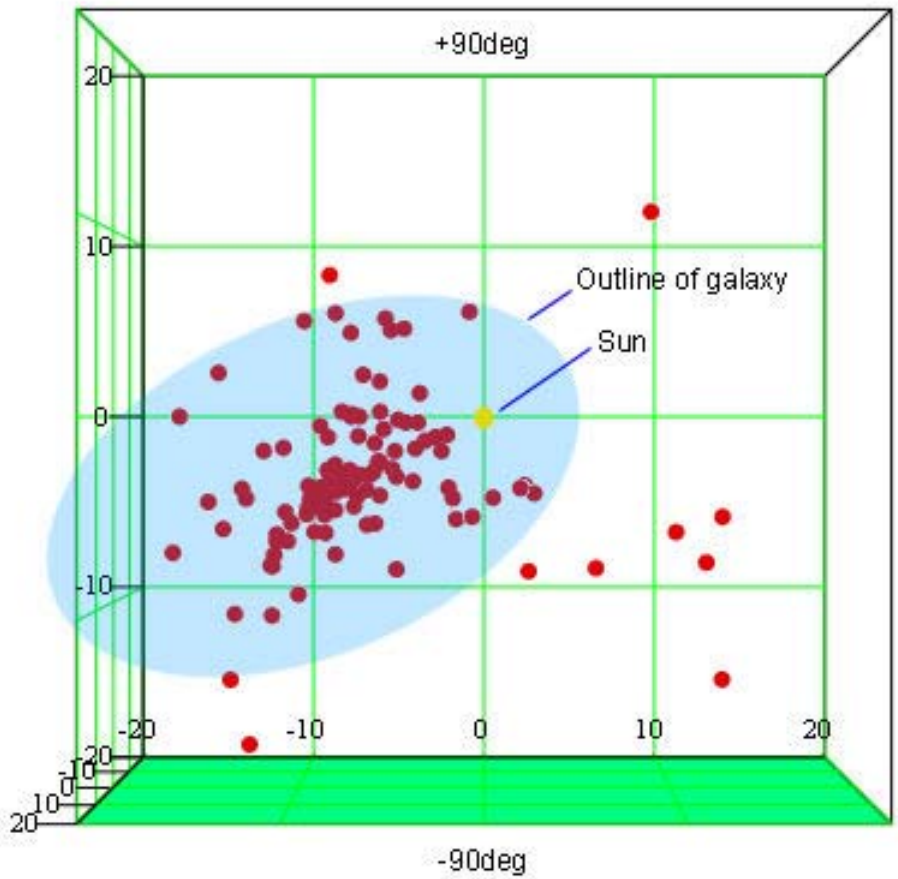
Bulge

- part of the disk? separate component? center of the halo?
- Metal abundances from very low to way above solar

Thick disk

- scale height ~ 1-2 kpc in the solar neighborhood, with almost all old population
- Stars 7-10 Gyrs
- Thickness too great to account for by slow drift after birth

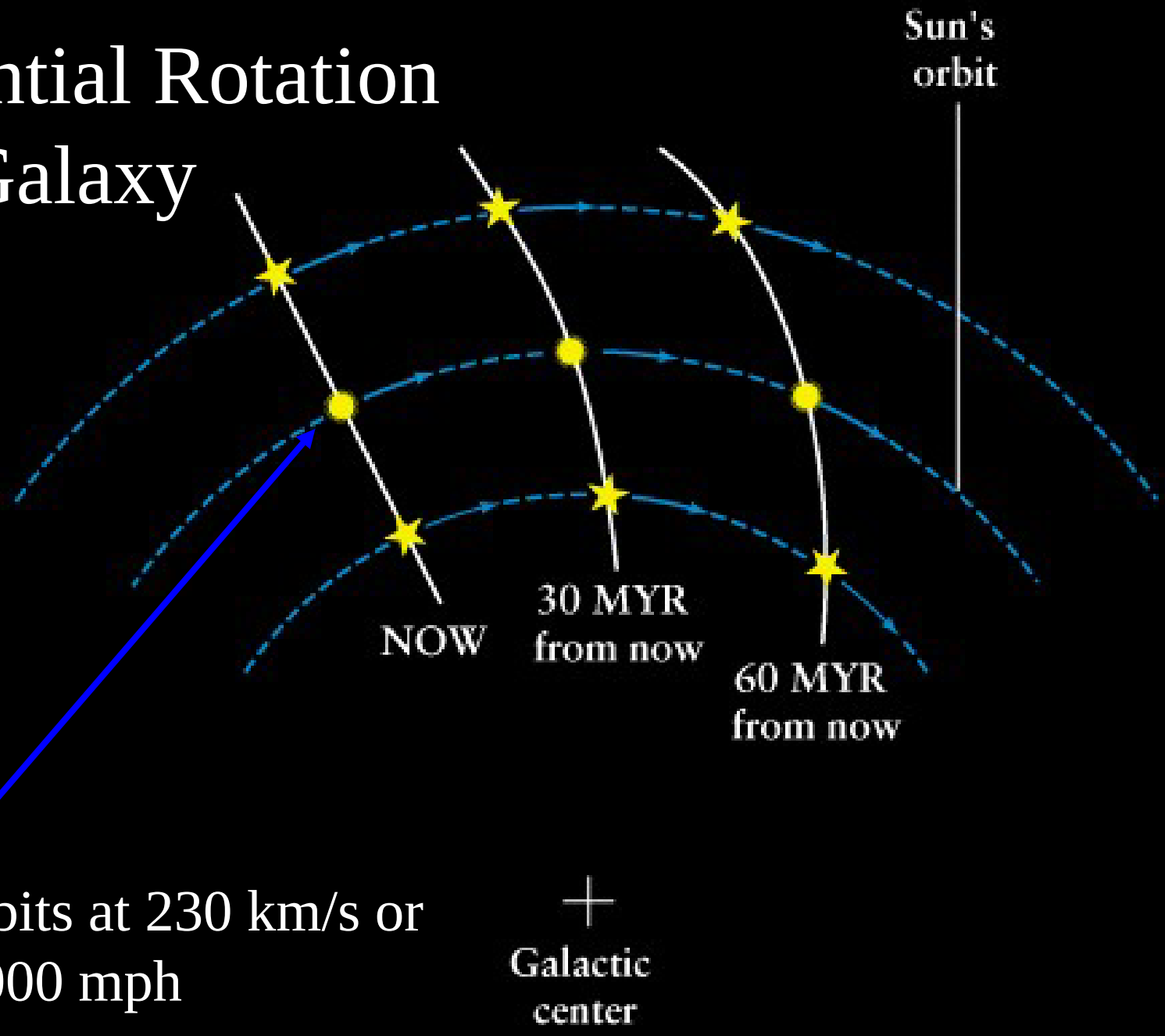
View from RA 0h, Dec 0deg (up is north)
Scales in kiloparsecs



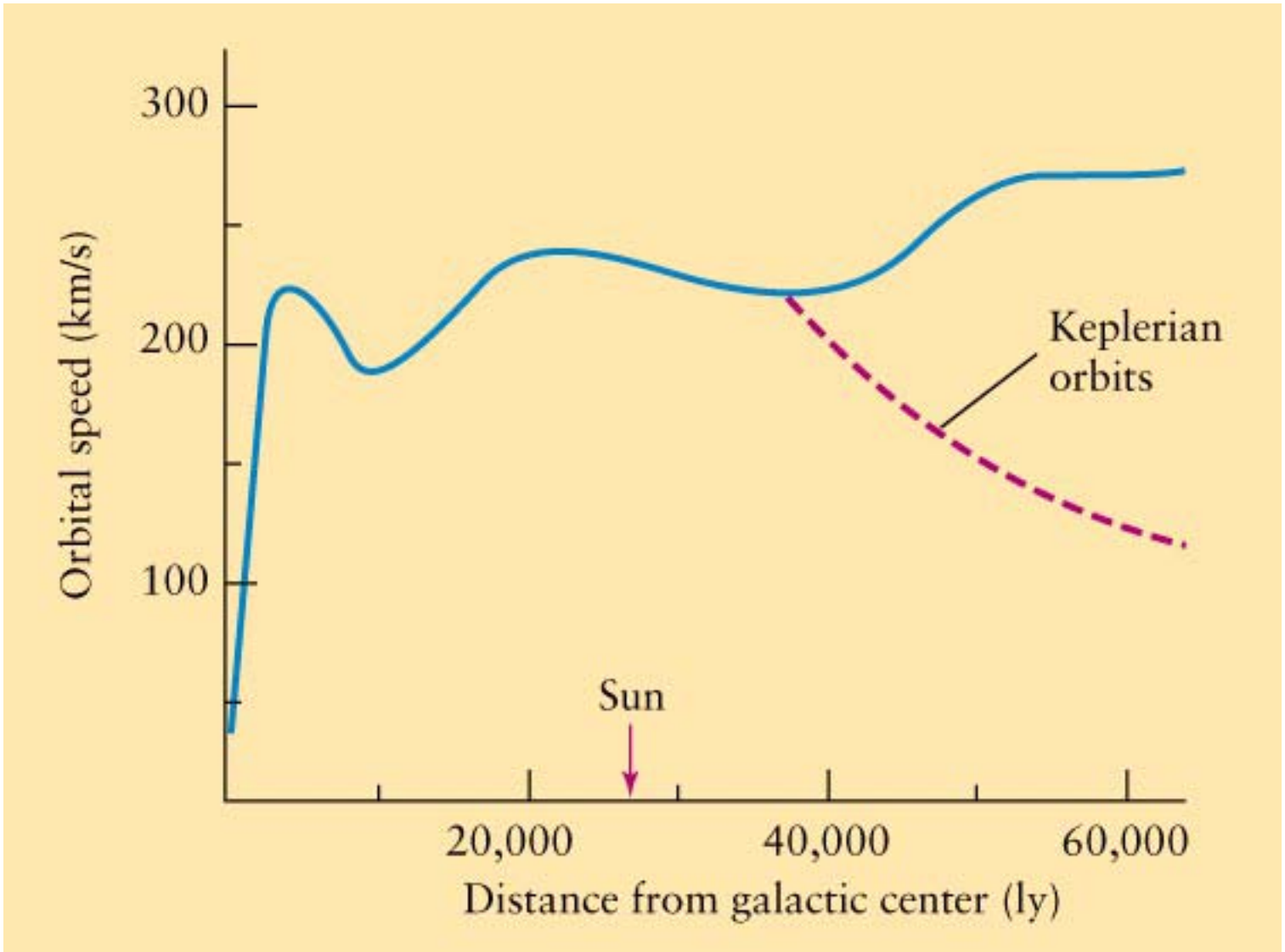
Plot of globular clusters in a 40x40x40 Kpc volume around Earth

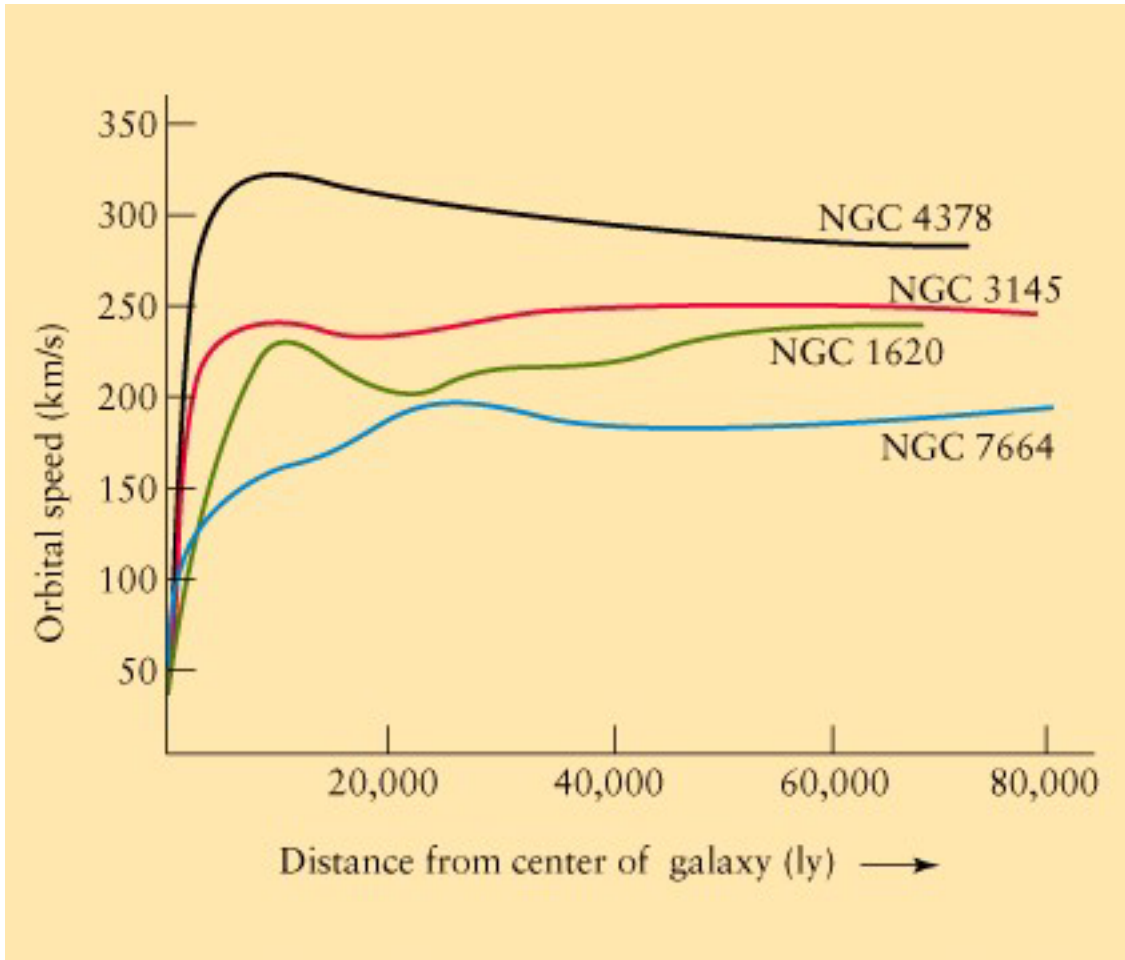
http://www.astrophotographer.com/Globular_plot.html

Differential Rotation of the Galaxy



The Sun orbits at 230 km/s or about 500,000 mph


300
200
100
Orbital speed (km/s)
Keplerian
orbits
Sun
20,000
40,000
60,000
Distance from galactic center (ly)


350
300
250
200
150
100
50
Orbital speed (km/s)
NGC 4378
NGC 3145
NGC 1620
NGC 7664
20,000
40,000
60,000
80,000
Distance from center of galaxy (ly)

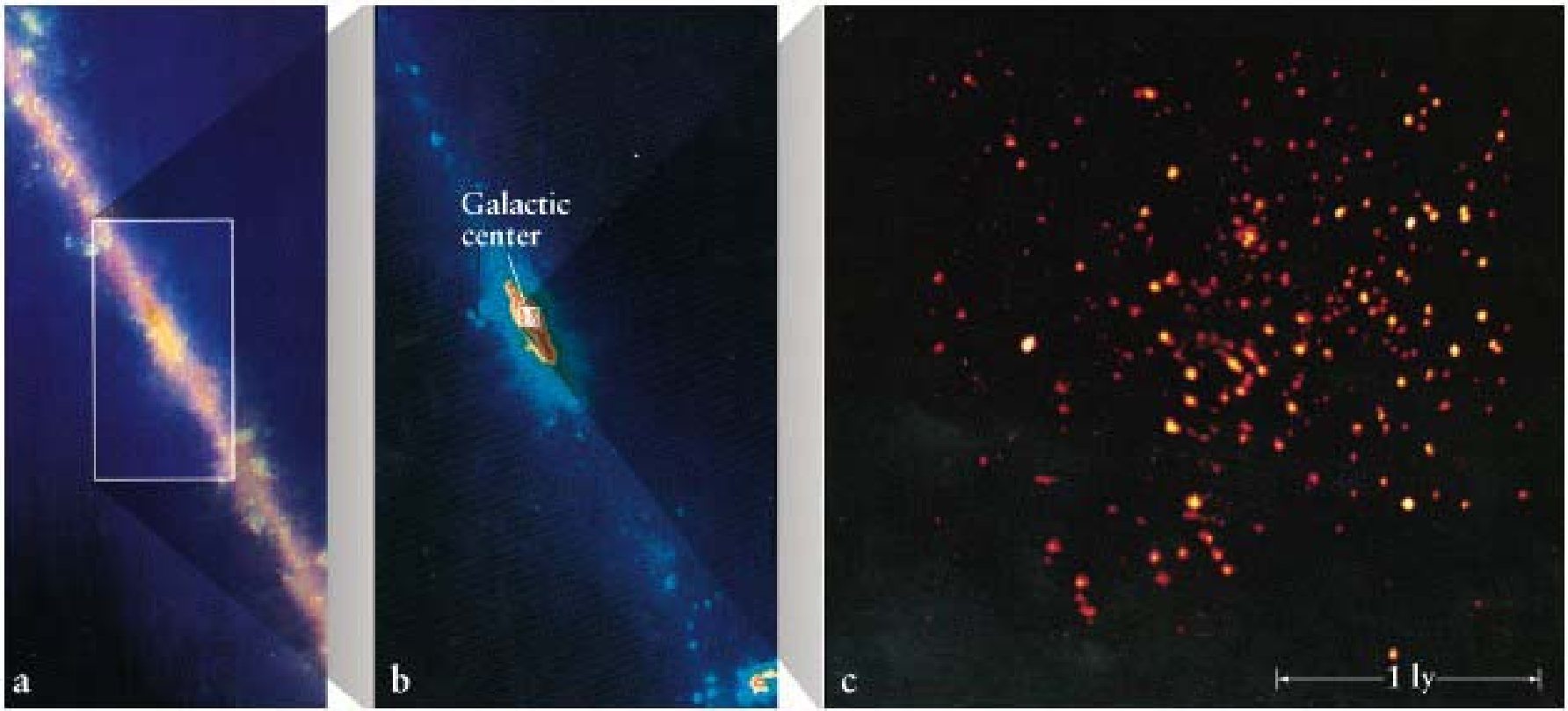
Most of the matter in the Galaxy has not yet been identified

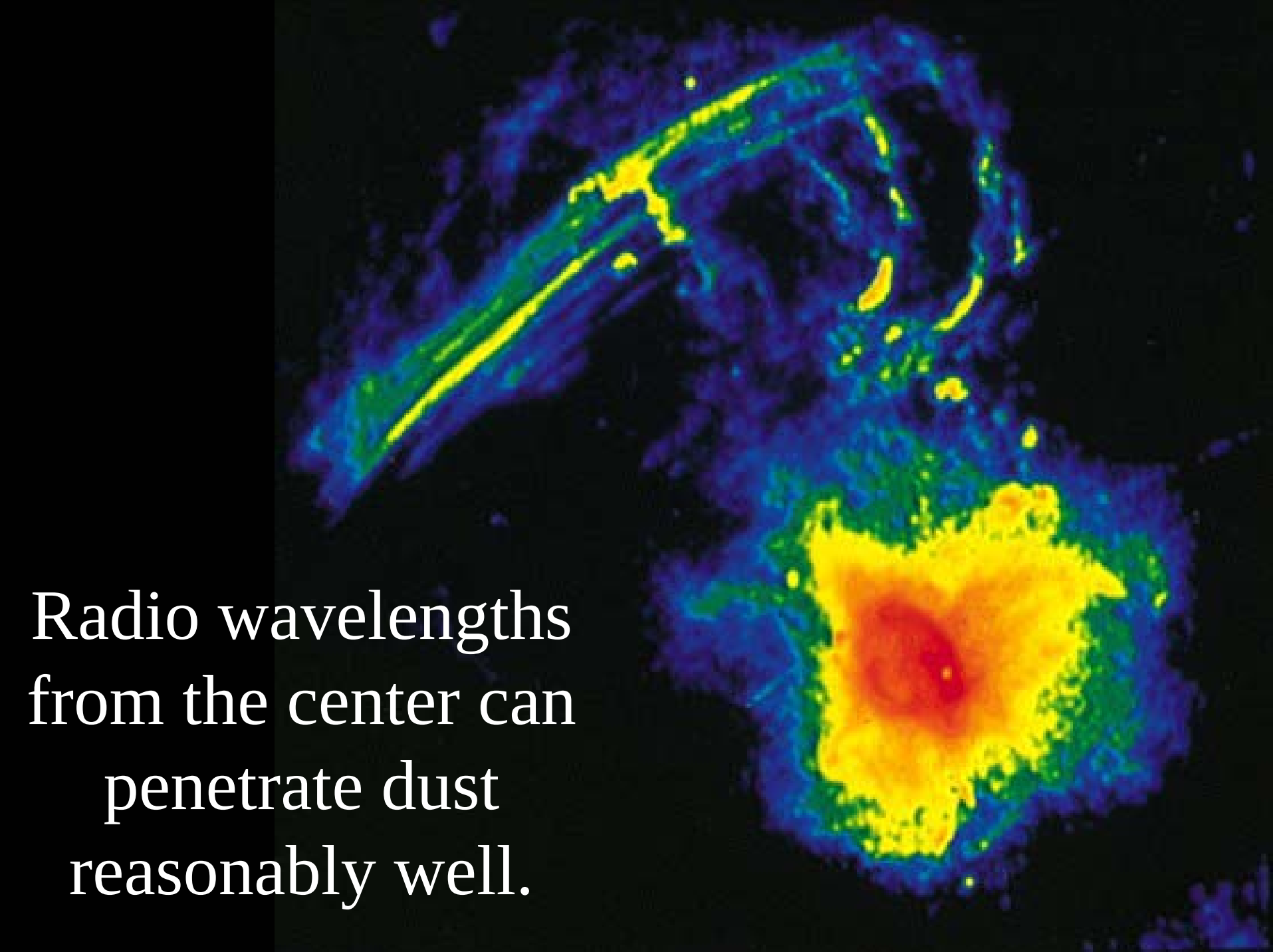
- According to Kepler's Third Law, the farther a star is from the center, the slower it should orbit
- Observations show that the speed in fact increases with distance from the center
- This could be due to gravity from extra mass we cannot see - called ***DARK MATTER***.

The galactic nucleus is also still poorly understood because dust obscures our view

- The center is located near the constellation of Sagittarius.

Infrared wave-lengths from the center can penetrate dust reasonably well.




Radio wavelengths
from the center can
penetrate dust
reasonably well.

What exactly is at the Center?

- ????????
- We observe gas flying around the center at enormous speeds of 200 km/s
- It would take about a million times the mass of the Sun to keep it from flying out of the center.
- A black hole?
- We observe supermassive black holes in the center of other galaxies.
- New X-ray telescopes are being designed to look carefully at exactly what the gas at the center is doing.

What did you think?

- *Where in the Milky Way is the solar system located?*

  The solar system is about 28,000 ly from the center of the Galaxy near the Orion spiral arm.

- *How fast is the Sun moving in the Milky Way?*

  The Sun orbits the center of the Milky Way Galaxy at a speed of 828,000 km per hour.

- *How many stars are in the Milky Way Galaxy?*

  The Milky Way has more than 200 billion stars.